The Effectiveness of Game-Based Learning Application Integrated with Computational Thinking Concept for Improving Student's Problem-Solving Skills

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Abstract. Game-Based Learning (GBL) and Computational Thinking (CT) have become essential tools in education as many studies successfully proved it effectiveness. However, the integration between both concepts into learning application is still lacking. Hence, this research aims to determine the effectiveness of using GBL applications which were developed by integrating CT concept for improving student's problem-solving skills. Integrating CT in the GBL means applying the CT concepts (such as abstraction, algorithm, decomposition, automation, and evaluation) through digital games specifically developed for computer science course in a primary school. In evaluating the effectiveness of the GBL for CT, this research has utilized a quasi-experimental design and enrolled a control group with the pretest and post-test assessments. At the end of the experiment, the achievement scores of both groups were collected, and the difference in problem solving effectiveness between the experimental (N = 24) and control (N = 25) groups was examined. The results of the analysis showed that the average post-treatment scores of the treatment group were significantly higher compared to the control group. It shows that the application of GBL for CT has affected or contributed 67% to student achievement in problem solving. Therefore, the study proved that the GBL for CT is effective to improve student's problem solving skills.

Keywords: Game-based learning · Computational Thinking · Problem solving skill · Computer science · Primary school

1 Introduction

Computational Thinking (CT) experts argue that individuals who master these skills can understand that developments in digital technology will be able to solve future problems [1]. This opinion is also in line with the aspiration of the Malaysian Ministry of Education (MOE) to produce students who competent in thinking skills and problem-solving skills as included in the Malaysia Education Blueprint (MEB) 2013–2025.

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CT should be one of the basic skills possessed by every individual instead of being only limited to computer experts [2]. Mastery of CT skills can help an individual to devise solutions to problems, design systems, and better understand human behavior [3]. Wing [4], explains that CT is a thought process that occurs repeatedly and is suitable for application in various fields or disciplines. Generally, CT is not limited to computer scientists or professional programmers only. On the other hand, when CT skills are linked with critical thinking and computer technology capabilities, CT can help all groups including teachers and students in thinking of new ways to understand and explain elements of human daily life and how problems can be solved more effectively. For examples, performing tasks we need to do today (decomposition), avoiding accidents by identifying hazard characteristics (pattern recognition), using a diary to organize tasks according to daily time or hours (scaling), or creating a set of instructions for colleagues (algorithm design) and so on.

Studies shown that CT can be integrated in various learning methods, and one of them is a GBL which can be implemented during teaching and learning whether as technology or learning media [5]. In addition, GBL is also seen to have a positive effect on student's problem-solving skills and knowledge acquisition while increasing their motivation and involvement during learning [6].

Integrating CT in the GBL approach means applying the CT concepts such as abstraction, algorithm, decomposition, automation, and evaluation through digital games with the aim of improving student's problem-solving skills. Based on the previous studies, there is still a lack of research that describe the CT concept integrated in GBL for subjects in schools that can improve problem solving skills among primary school children. Most studies focused only on the subject content specifically in Science, Technology, Engineering, and Mathematics (STEM). In addition, some studies on GBL development focused on whether digital games were effective in terms of promoting students' learning outcomes and motivation, while little research has been conducted to explore problem solving skills improvement among students. Moreover, a study conducted by [7] in 2019 explained that majority of their respondents have not been exposed to CT concepts.

2 Computational Thinking Skills in the 21st Century Learning

Most researchers agree on the importance of understanding the concept of CT for use in education for the 21st century learning [8]. This opinion is also supported by Dede, Mishra and Voogt [9], who stated that the concept of CT is a skill that needs to be comprehended to students nowadays because it is related to other vital 21st century skills such as problem solving, critical thinking, productivity, and creativity. In supporting this effort, academicians in several countries have sought to make CT the main pillar in their respective education whether in business and trade, biology or biomedical engineering curricula [8]. In relation to this, several approaches have been proposed by [10] to ensure that students comprehend the fundamental concepts of CT including:

a. design solutions to problems (using abstraction, automation, algorithm creation, data collection and analysis),
b. implement design (appropriate programming),

c. test and debug,
d. model, run simulations, carry out system analysis,
e. reflect on communication practices and skills,
f. using vocabulary,
g. recognize abstractions and switch between different levels of thinking from different types of thinking,
h. abstractions,
i. innovation, exploration, and cross-discipline creativity,
j. problem-solving, and
k. using various learning strategies.

Based on the discussions mentioned above, it can be clearly concluded that the concept of CT must be explored in more depth and seriousness. This covers the use of terms, understanding of concepts and practices across various levels and fields of study. Thus, this research aims to study or identify the appropriate CT concepts for integration into the GBL application. Example of studies (refer to Table 1) have been conducted which described how the CT concepts were applied in their respective curricula and fields. The trend of the studies shows how the CT concept is developed starting from the application of the concept to the design of a new curriculum. Most conclusions from these studies focused on some of the CT concepts only. This shows that there is still a lot of room for studies related to the concept of CT by either integrating it in the curriculum or introducing it in non-computer science subject.

CT in education has significant potential in improving student problem-solving skills at many education levels. In this regard, Ministry of Higher Education of Malaysia has outlined clear objectives in the introduction of CT starting in 2017 [16]. Among the objectives are:

a. Assisting teachers to better guide their students in finding new solutions to problems that seem impossible to solve.
b. Assisting teachers to improve a teaching or learning practice or activity.
c. Enriching the teaching of teachers and student exploration in a subject even without the use of or access to technology.
d. Increasing students' confidence particularly to face problems that are less clear, complex, or open.

Therefore, teachers can use any new solutions by integrating CT to improve teaching and learning practices, as an example through GBL.

Table 1. CT concept and past studies.

Researcher	CT concept	Description
Barr and Stephenson [10]	Abstraction, algorithm, decomposition	Students are observed as able to use the concept of CT in solving problems, talk about the concept of CT in discussions, and show the results of work through various means
Angeli et al. [11]	Abstraction, algorithm, decomposition	This study focuses on two issues namely CT framework-based curriculum design, and CT knowledge among teachers
Mohanty and Das [12]	Abstraction, algorithm, decomposition, pattern recognition, and pattern generalization	This study integrates the CT approach in What-Why-How (WWH) learning model to to resolve some of the challenges associated with learning skills among new university students
Turchi, Fogli, and Malizia [13]	Problem-solving, algorithm, abstraction, decomposition, recursive, heuristics, representation, and evaluation	A key aspect of this research is the use of collaborative gameplay to develop CT skills among secondary school students
García et al. [14]	Abstracting, algorithm, decomposition, logical reasoning, evaluation	This study introduced Artificial Intelligence concept that fosters CT skills among school students by using machine learning technique
Hooshyar et al. [15]	Algorithm, pattern recognition, debugging, and logical reasoning	The study revealed that the integration of adaptivity into educational computer games can improve students' CT not only in relation to conceptual knowledge but also CT skills

3 Game-Based Learning and Computational Thinking

GBL is another essential approach for the 21st century learning [17] where it promotes learning motivation and enhances problem solving skills among students. Therefore, integrating CT concept in GBL would provide more effective learning environment to them.

The study of [18] states that they have developed a game framework that allows students to competent some skills during a gameplay. The findings of this study clearly indicated that there is a positive relationship when GBL and CT are integrated. The skills in question are:

a. Creating and using algorithms to solve specific problems.
b. Evaluating an algorithm by determining the appropriate criteria.
c. Applying the CT method to the problem.
d. Debugging algorithms and detecting logic error.
e. Simulating algorithm and observing the effects that need to be considered in the abstraction.

These findings were also supported by Grizioti and Kynigos [19, 20]. Their study focuses on examining a) the level of meaningful mastery of CT skills through student involvement and b) how progressive involvement in game modding can support the development of these skills. In the study they tried to explore the possible contribution of game modification (or modding) to CT skill development by discussing the design of ChoiCo (Choices with Consequences) game, in online environment. The research findings showed that through game design and development (of GBL) students were able to understand the concept of CT very well. Table 2 shows the CT concept mastery and GBL level of development.

Another example is a study conducted by [21] which have developed 3 types of board games in *Crabs & Turtles: A series of computational adventures.* Their games aimed to introduce the basic concepts of coding to students aged 8 and 9 years. They have described the game design in detail to describe the GBL development process to allow for reproducibility if necessary. According to them, the cognitive ability and concept of CT (algorithm) has been able to improve during the GBL design process, programming, or coding.

Table 2. CT skills across progressive involvement in game modding

GBL level	CT skills
Use	Pattern recognition, automation
Fix	Pattern recognition, pattern execution, automation, abstraction
Create	Pattern recognition, decomposition, pattern execution, abstraction, automation

4 Problem Solving Skills

Problems are usually associated with something negative that can cause people to experience emotional stress and anxiety [22]. However, problems can also have a good effect when it becomes a useful input or source of stimulus to the human brain. Rickards and Moger [23] stated that "a problem is a situation that people face when they need something and they do not know how to obtain it". Human desire is unlimited and is constantly evolving according to technological developments in line with employment or social life needs. Therefore, every problem needs to be solved in the most effective way to achieve the best results.

Mumtazah and Husna [24] defined problem solving as an effort to find alternative ideas and measures to overcome the existing obstacles to achieve a goal through complex and complicated mental processes. Effective solutions can increase self-confidence and preparedness for current and future life challenges. Among the commonly taken steps in dealing with problems are as shown in Fig. 1.

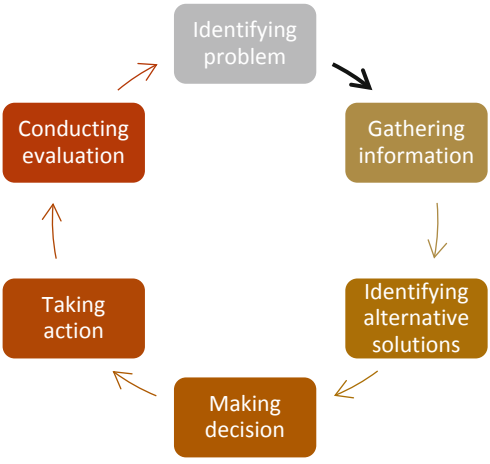

Fig. 1. Problem solving process (Source: [24])

In addition, Voskoglou and Buckley [25] defined problem solving as an activity that involves the use of cognitive and physical means to overcome a problem by producing better suggestions. Voskoglou and Buckley [25] stated that most students today face difficulties in solving problems in real life. This is because they do not have enough knowledge and skills. Nevertheless, there are many methods and theories that can be used to solve problems.

In relation to that, CT is also a problem-solving process because CT is an approach that combines logic skills with the core concepts of computer science [26, 27]. In addition, the Computer Science Teachers Association and the International Society for Technology in Education [26] have defined CT and operational problem solving as important references for easy understanding and implementation. According to them, CT is a problem-solving process that includes the following features:

a. Formulating problems with methods that allow humans to solve them using computers or other technologies.
b. Organizing and analyzing data logically.
c. Representing data through abstractions such as models and simulations.
d. Automating solutions through algorithmic thinking (a set of structured steps).
e. Identifying, analyzing, and implementing possible solutions with the goal of achieving more effective and efficient methods or means through the combination of existing measures and resources.
f. Generalizing or transferring the problem-solving process implemented to various other problems.

In general, CT is an effective thinking process in solving student's problems and has a significant influence on their academics [28]. Therefore, this study will test the effectiveness of GBL application for CT in improving student's problem-solving skills.

5 Methodology

To evaluate the effectiveness of the GBL for CT, a quasi-experimental design study was implemented involving 49 primary school students where the experimental group learned with Computational Thinking Game Based Learning (CT GBL) application, while the control group used a Problem Solving Game Based Learning (PS GBL) application. CT GBL is an application developed using the GBL design model integrated with CT while

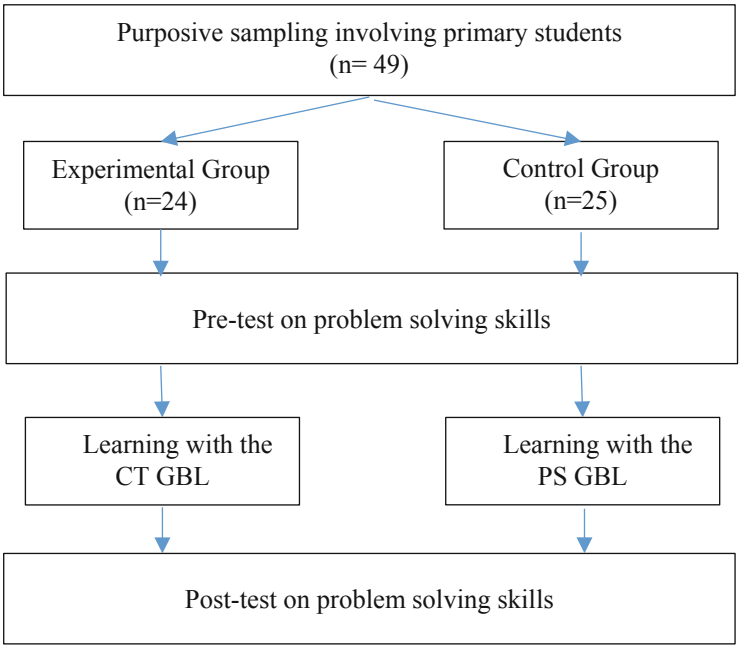

Fig. 2. Experimental procedure

the PS GBL application is developed using the problem-solving theory. The experimental process followed in this study is illustrated in Fig. 2.

5.1 Procedure

At the initial stage of this study, a Basic Computer Science subject teacher was assigned in assisting the experimental procedure. He was briefed on the procedure to ensure that he has a clear understanding how the process taken placed. Group of students was assigned randomly according to their classes either as the experimental group (n = 24) or the control group (n = 25). Learning session on both groups were carried out by the same teacher so that this research could avoid the possible effect of different teachers on the results.

At first, the research started with students in both groups answering pre-test for measuring problem-solving skills which took 75 min duration. Then the results of these pre-test were recorded. Secondly, students in control group learned about problem-solving for programming topics (identical topics for both groups) from the teacher using PS GBL as a learning tool. This GBL application was developed traditionally using problem solving theory. Then, students in experimental group took the same learning session from the same teacher using the CT GBL. CT GBL is an application developed specifically using the GBL design model integrated with CT concepts. Each group of students were placed in school computer lab equipped with 25 computers. The experiment was conducted for 4 days in which one hour was allocated for each session for both groups. Students from both groups were supervised by the subject teacher and the researcher acted as a facilitator who assisted in technical matters. Finally, when the learning sessions were completed, the students were asked to answer the post-test questions which held in 75 min and the results of post-test were recorded.

5.2 Instrument and Data Analysis

This effectiveness assessment is measured through the analysis of student achievement (marks) in the pre-test and post-test questions. The tests were used to assess student problem solving skills before and after the experiment. These pre-test and post-test questions sets were adopted from the OECD's Programme for International Student Assessment (PISA) [29]. The test question includes five dimensions: (1) development of CT skills and (2) problem-solving skills, (3) basic concepts of programming, (4) collaboration in groups, and (5) robotics education. The total mark of each test is 100.

According to Shadish, Cook, and Campbell [30], the one-way Analysis of Covariance (ANCOVA) technique is very suitable for use in quasi-experimental research where participants involved in pre- and post-test. Moreover, according to Piaw [31], this test is a technique that can be used to improve the validity of the data that has been analyzed. The ANCOVA technique can determine the extent to which an independent variable influences the dependent variable without being influenced by the variable [32].

6 Findings of the Experimental Study

This section will further explain the findings of the experiment on the effectiveness of CT GBL compared to PS GBL application in improving student's problem solving skills. The data were obtained from both groups who were exposed to CT GBL or PS GBL.

Firstly, Table 3 shows the mean of pre-test scores of the control group (M = 53.64, SD = 11.42) and the experimental group (M = 43.46, SD = 13.47), while in Table 4 illustrates the Levene's test results to test the samples have equal variances.

Table 3. Mean of pre-test scores for control and experimental groups

Group	N	Mean (M)	Standard deviation
Control	25	53.64	11.42
Experimental	24	43.46	13.47

Table 4. Levene's test for homogeneity of variances

		Df	*F*	*p*
Pre-test scores	Assumption of homogenous variance	47	2.195	.145

The insignificant Levene's test results ($p = .145 > .05$) in Table 4 have also proven that the pre-test scores of both groups are homogeneous and suitable for making assumptions of population homogeneity of variances in t-tests. In connection to this result, Table 5 shows the pre-test mean values of the control group (M = 53.64) was significantly higher than the pre-test mean values of the experimental group (M = 43.46). Thus, the analysis found that there was a significant difference ($t(47) = 2.86$, $p = .006$) in mean pre-test scores between control group and experimental group at a significance level of 0.05.

Table 5. Comparative analysis of pre-test independent samples t-test

Group	*M*	*df*	*t*	*P*
Control	53.64	47	2.86	.006
Experimental	43.46			

Next, the analysis proceeds to the comparison of pre- and post-test scores between control and experimental groups. The findings on descriptive analysis on the test scores of the experimental and control group in Table 6 show that there were differences in the mean values in the pre- and post-tests scores. The mean value of the control group was found to have increased to 66.38 in the post-test from 43.46 in the pre-test; a difference

of 22.74 in mean value with a standard deviation of 13.364. The increase is enormous compared to the mean value of the control group. The table also shows the mean value of the control group in the pre-test was 53.64, increasing to 65.40 in the post-test with a difference in mean value of only 11.76 and a standard deviation of 13.319.

Table 6. Comparative analysis of pre-test and post test for both groups

Group	Pre-test mean	Post-test mean	Mean difference	SD
Control	53.64	65.40	11.76	13.319
Experimental	43.46	66.38	22.74	13.364

To achieve the main objective of this research whether there is a significant difference in mean of student scores in problem solving between group of CT GBL and PS GBL, the ANCOVA analysis was performed to test the research hypothesis. The hypothesis aims to identify whether there is a significant difference in student achievement between the control group and experimental group in post-test scores by making pre-test scores as covariates.

Prior to conducting an ANCOVA analysis, the Levene's test should be performed to verify whether the assumptions of homogeneity of variances have been met for both. The p-value in the Levene's test should not be significant (p-value $>.05$), meaning the assumptions of homogeneity of variances have been met [33]. If the interaction results are significant then the results of ANCOVA are meaningless and ANCOVA should not be done [34].

The results of the Levene's test (Table 7) show there was insignificant value ($F(1,47) = 0.945$, $p = .336 > .05$). These results also indicate that the variances for both groups are homogenous. Therefore, it is significant to use the ANCOVA analysis to test the hypothesis of this study [35].

Table 7. Levene's test for homogeneity of variances

	F	*df1*	*df2*	*p*
Scores	.945	1	47	.336

In this research, the use of pre-test scores as covariates is to equalize the achievement between the experimental group and the control group in terms of mastery in the pre-test. ANCOVA analysis eliminates the covariates effect on the relationship between pre-test (independent variable) and post-test scores (dependent variable).

Table 8 shows that the adjusted mean for the experimental group score, $M = 71.75$ was different and significantly higher compared to the control group, $M = 60.24$. This analysis shows that the achievement of students in the experimental group was performed better than the control group in the post-test after the covariate effect (pre-test) was considered.

Table 8. Descriptive statistics for ANCOVA with covariates (dependent variable: post-test)

Group	*M*	*Std. error*
Control	60.24	.801
Experimental	71.75	.819

Next, after the ANCOVA analysis was conducted, the results shown in Table 9, indicate that [F (1,46) = 93.62), p = .00] with a value of η^2 (partial Eta squared) at .67 values. Based on these findings, students that having learned with CT GBL application have affected or contributed 67% to student achievement. In addition, the result also revealed that both group on post-test scores are significantly different when the effect of their pre-test scores was excluded.

Table 9. ANCOVA analysis of problem-solving skills (pre-test scores as covariates)

	Total squared	*df*	*Mean squared*	*F*	η^2	*Sig. (p)*
Pre-test scores	7824.19	1	7824.19	529.72	.92	.00
Student group	1382.78	1	1382.78	93.62	.67	.00
Error	679.44	46	14.77			
Total	221168.00	49				

This significant difference in mean allows the researcher to accept the hypothesis of this study that the adjusted mean of student achievement in problem solving skills using GBL for CT is significantly higher than PS GBL application. This finding shows the effectiveness of the CT GBL compared to the PS GBL in improving students' problem-solving skills.

7 Discussion and Conclusion

The objective of this research is to determine the effectiveness of GBLapplication integrated with CT concept for improving student's problem-solving skills. To determine the level of problem solving skills among students, they were assessed based on pre- and post-test scores and grouped into control or experimental group. This research implemented a quasi-experimental study as discussed in Sect. 5. There are two types of GBL applications used in this experiment, namely CT GBL (for the experimental group) and PS GBL (for the control group). However, this study can be enhanced by conducting testing on the game usability, mobility, playability, and learning content of the CT GBL and PS GBL as suggested by [36].

The results as discussed in Sect. 6 were analyzed using the ANCOVA and the pre-test scores as covariates. The ANCOVA analysis was able to eliminate the influence of pre-test and show the extent of the effect of CT GBL on student achievements. The results

showed that the mean post-test scores of the experimental group were significantly higher than the control group. According to the findings also indicated that the CT GBL has affected or contributed 67% to student achievement in problem solving. These findings are in line with the research conducted by Kow, Peter, Mahmud, Mohd Daud, and Ayub [37] who used GBL to observe the relationship between playing computer games and problem solving skills. Siong and Osman [38] also stated in their study that the use of GBL applications in learning chemistry concepts have improved student's 21st century skills in particular the problem-solving skills.

Although there has been some research done in the field of CT and GBL, there is a lack or no further studies that integrate these two fields in one framework. Therefore, this research can contribute new discoveries to knowledge and also help students to improve problem-solving skills. It will also serve as a guideline for teachers and the government to develop more effective educational materials that can contribute to the national education agenda for the 21st century learning.

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